

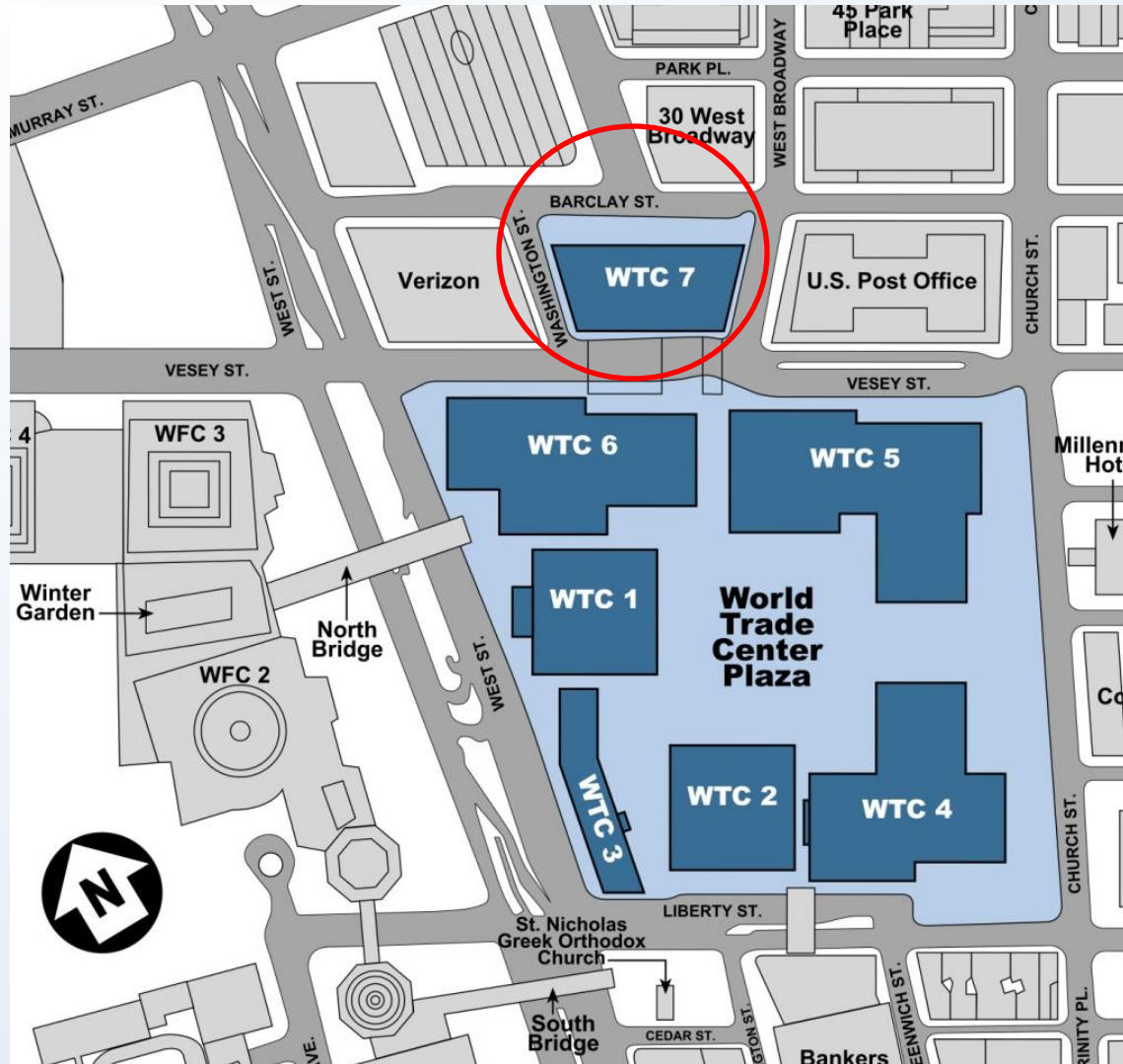
NIST Response to the World Trade Center Disaster

**Federal Building and Fire Safety Investigation
of
the World Trade Center Disaster**

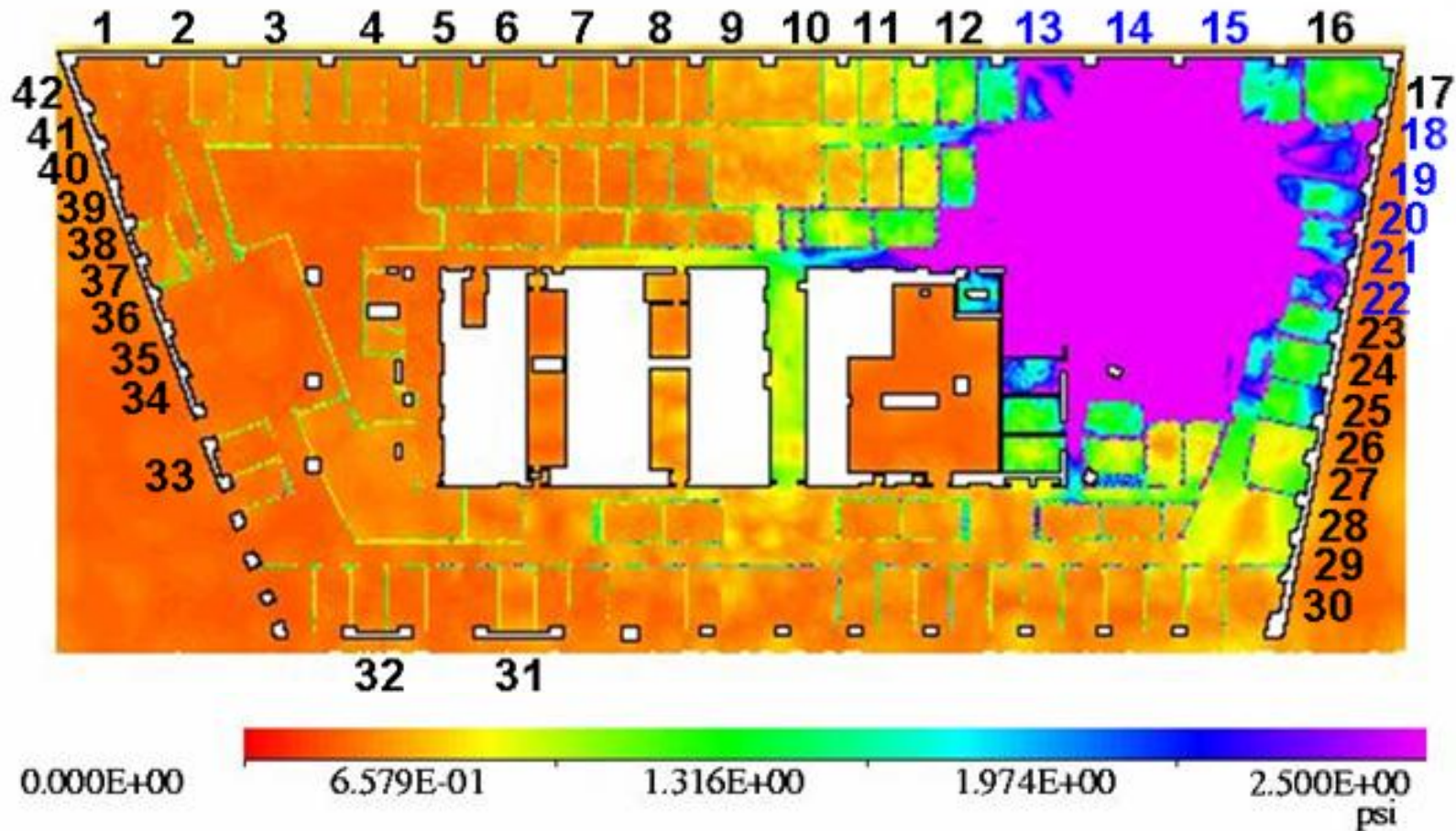
August 21, 2008

**Dr. S. Shyam Sunder
Director and Lead Investigator
Building and Fire Research Laboratory
National Institute of Standards and Technology
U.S. Department of Commerce**

World Trade Center 7 Location

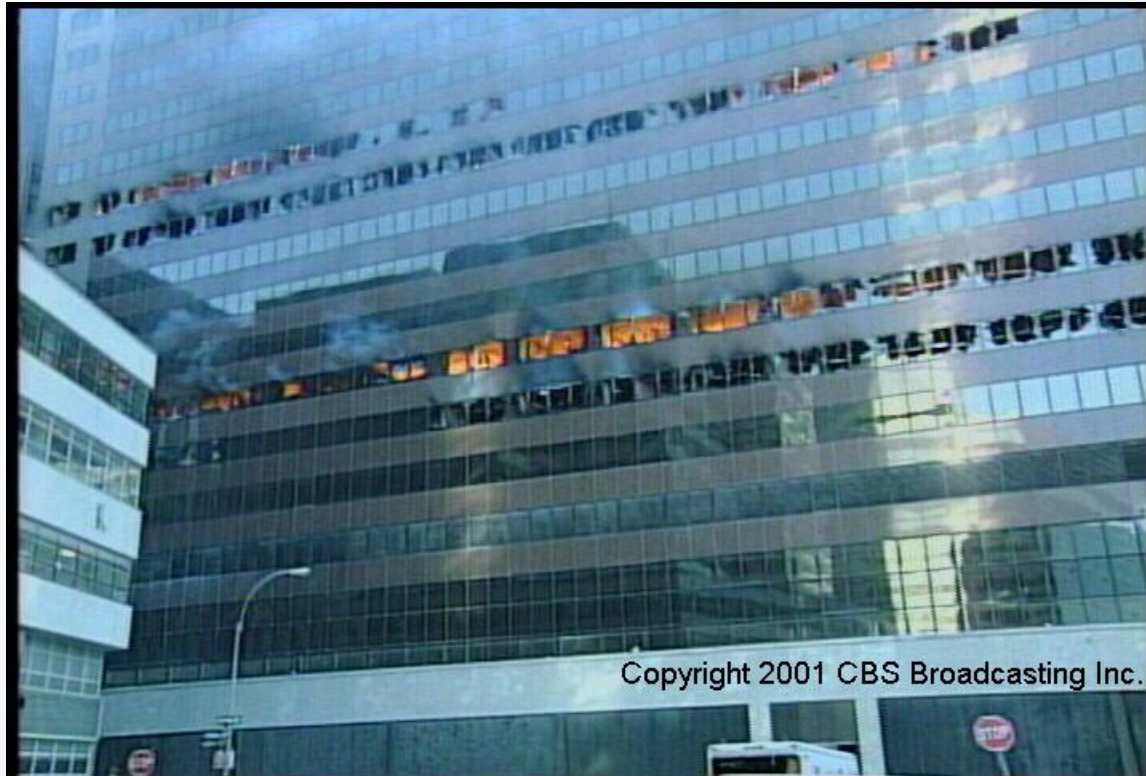


Hypothetical Blast Simulations



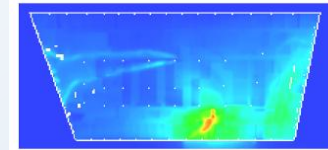
Peak over pressures for 9 lb shaped charge.

Fire Growth and Spread

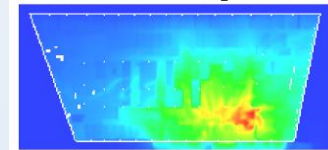


Progression of fires
on Floor 12

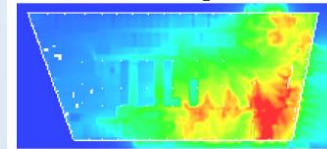
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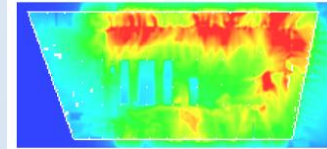
2:00 pm



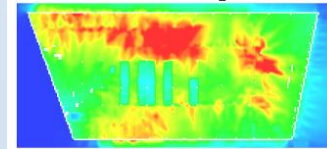
3:00 pm



4:00 pm



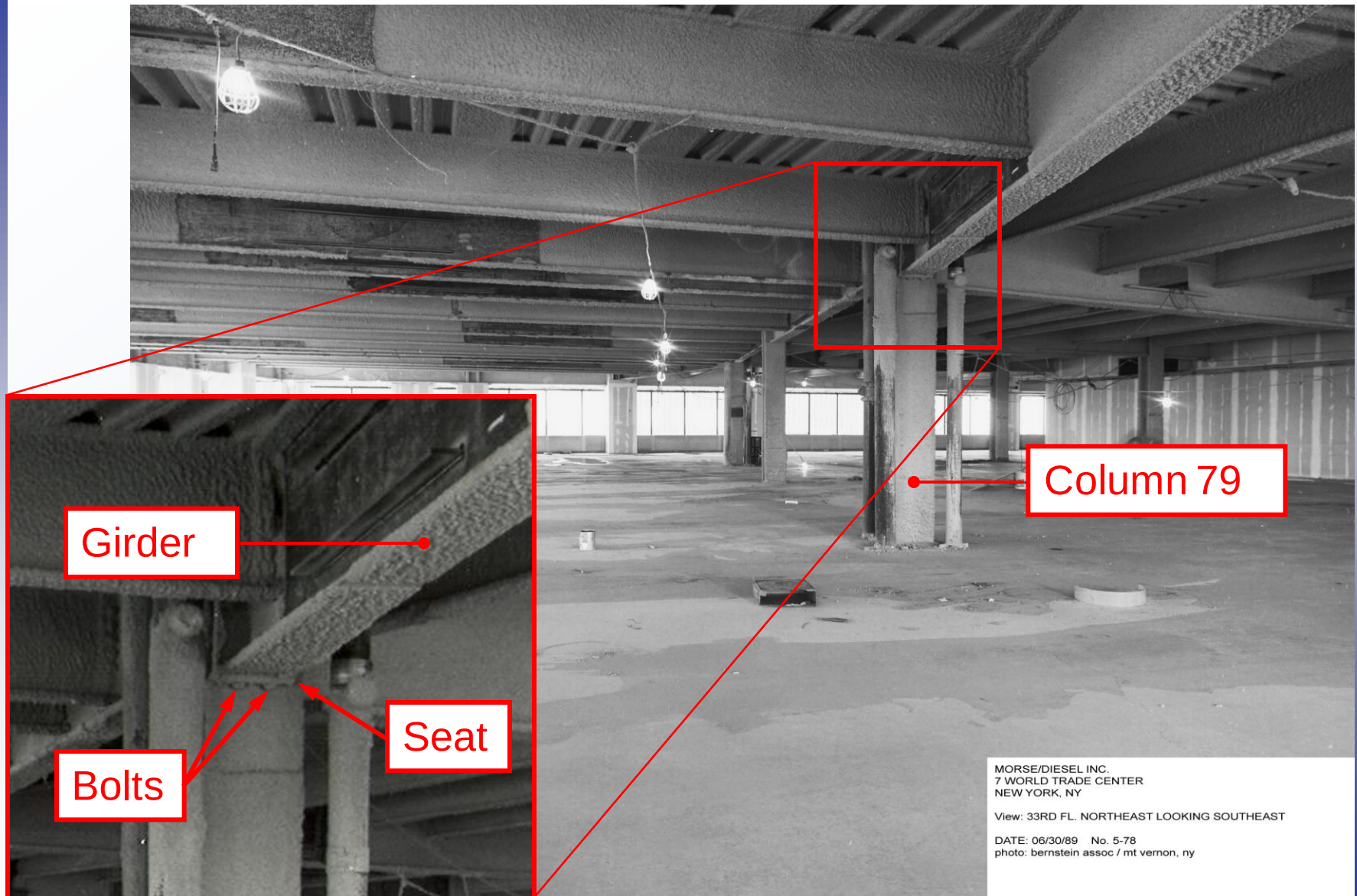
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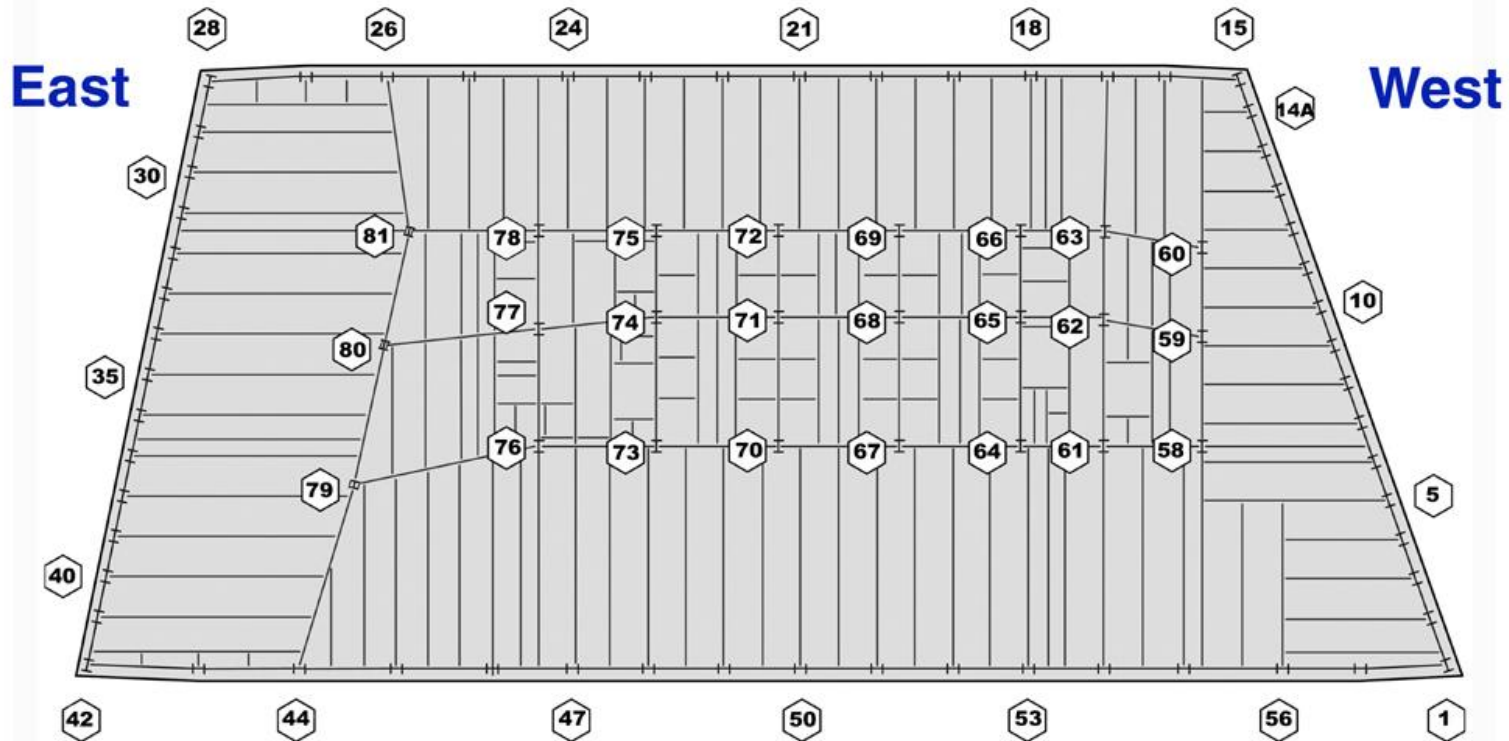
Slice
temp
C



North East Floor System Near Column 79

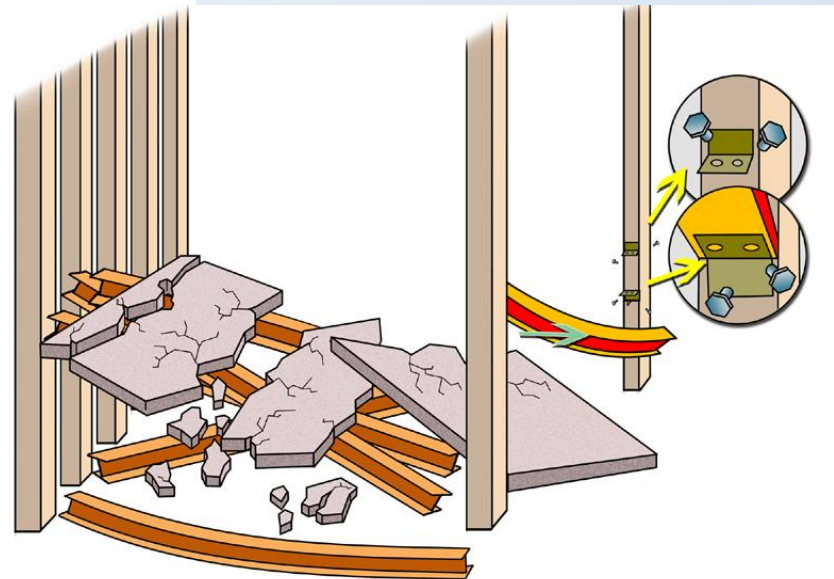
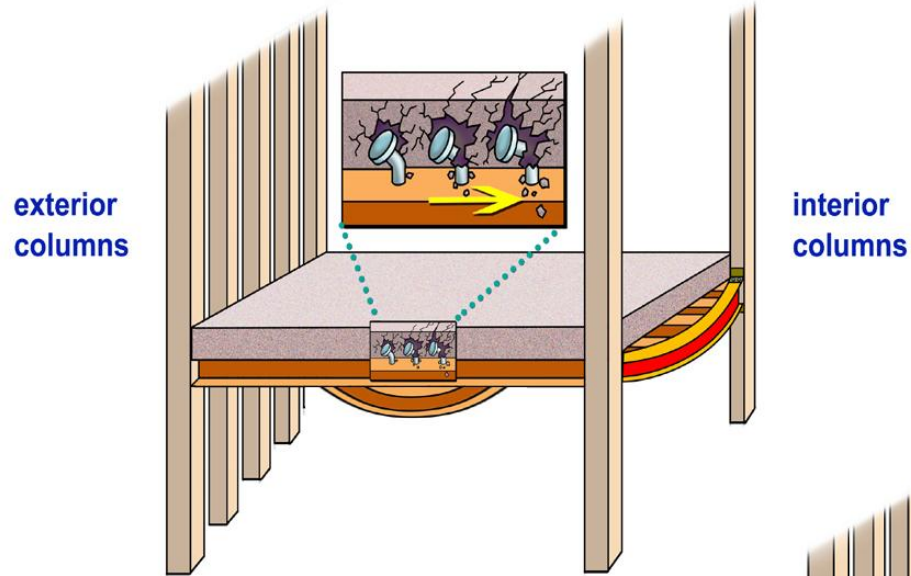


Typical Layout: Interior Columns, Floor Framing

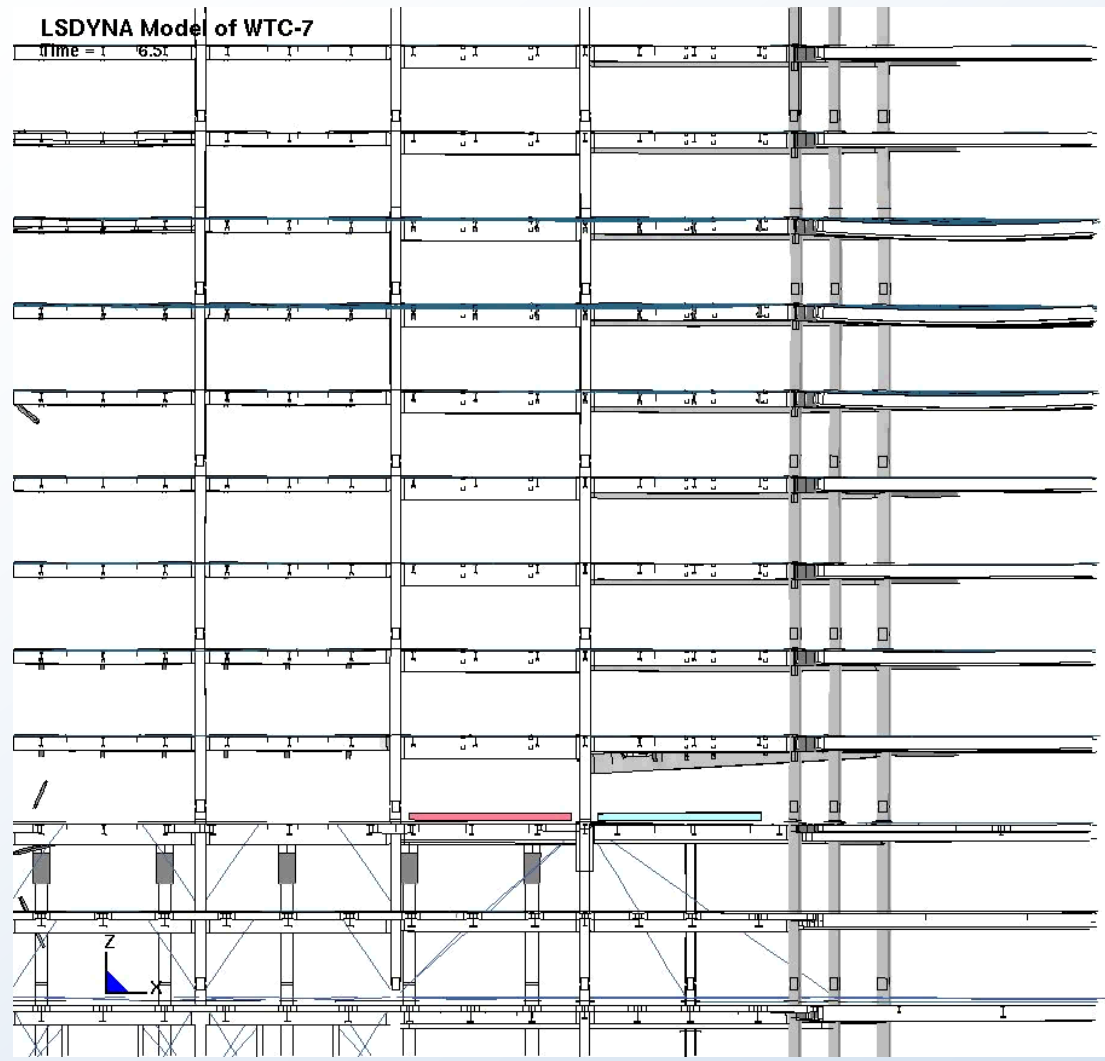


WTC 7 Typical Floor

Thermal Expansion Causes Floor Failures



Collapse Initiation– Physics-Based Model



Collapse Initiation Observations

Exterior Observations

- ❑ **East Penthouse Kinks**
- ❑ **Windows break on East Side of North Face**

East Penthouse Kink

Window Breakage



Vertical Collapse Progression

14th Floor

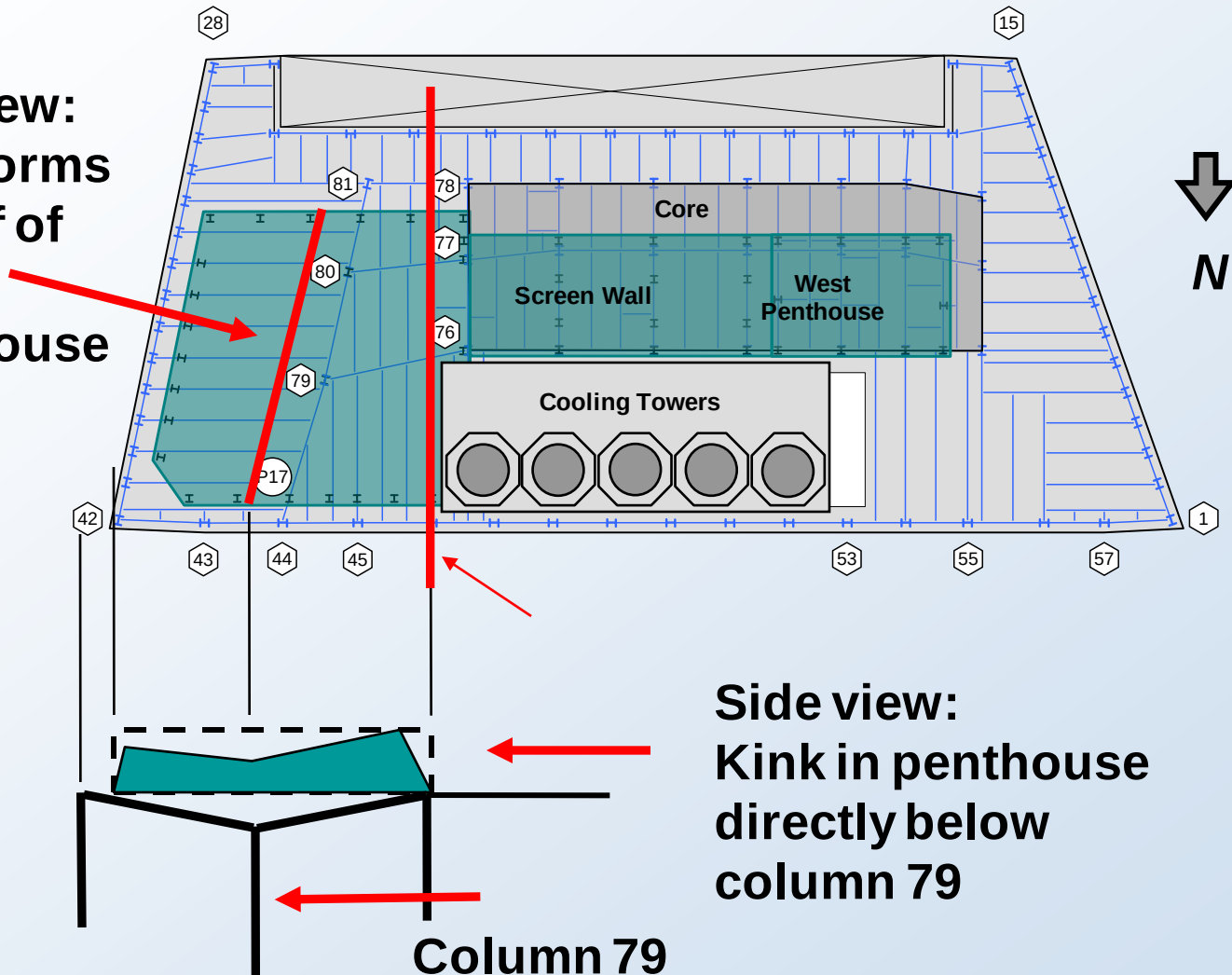
Column Buckles

7th Floor

Floors Fail

Penthouse Layout Overlaid on Floor Framing

Top view:
Kink forms
in roof of
East
Penthouse



Comparison of Visualization and Video



Visualization Model of WTC Collapse

LSDYNA Model of WTC-7
Time = 8.5



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Key Recommendation

Building owners, operators and designers should evaluate fire performance of structural systems, especially

- **Long-span floor systems;**
- **Connections not designed for thermal effects**
- **Asymmetric floor framing**
- **Composite floor systems**

Possible Options for Developing Retrofits

If thermal effects concerns are identified in a building:

- **Strengthen connections**
- **Strengthen floor framing**
- **Increase structural redundancy**
- **Add additional fireproofing in vulnerable areas**

Take Away Messages

- **The reason for the collapse of World Trade Center 7 is no longer a mystery**
- **WTC 7 collapsed because of fires, fueled by office furnishings**
- **It did not collapse from explosives or from fuel oil fires**

Questions and Answers